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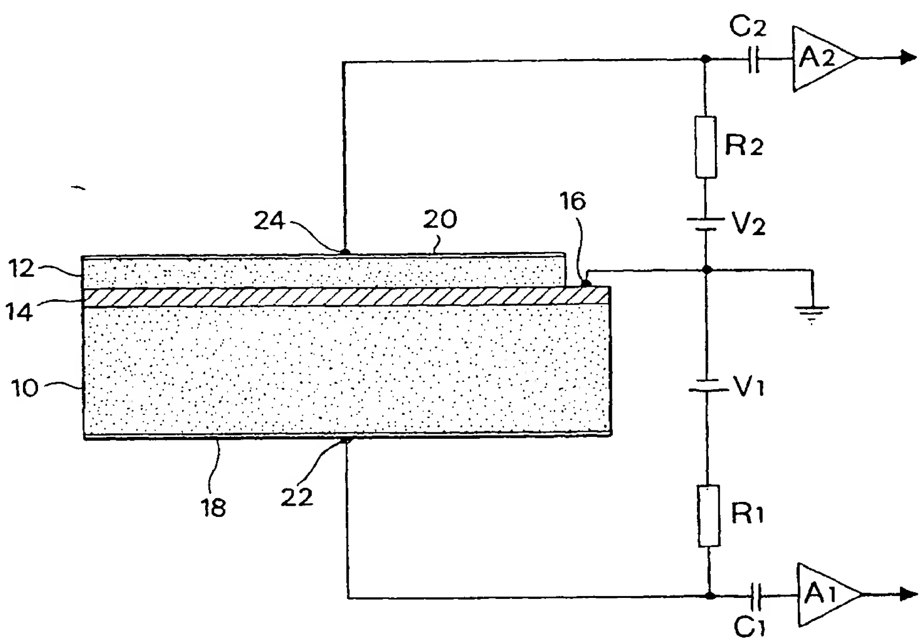
(54) Title: DETECTOR FOR IONISING RADIATION



(57) Abstract

A detector for ionising radiation comprises first (10) and second (12) diamond detector elements which are connected to a common contact (14). The two detector elements are of differing thickness and are optimised for the detection of different types of radiation, so that the detector simultaneously provides two output signals indicative of different kinds of radiation incident on the detector.

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DETECTOR FOR IONISING RADIATION

BACKGROUND OF THE INVENTION

This invention relates to a detector for ionising radiation.

Radiation detectors comprising diamond have been proposed which are optimised for the detection of different types of radiation. For example, radiation comprising heavy particles such as alpha particles is usually absorbed close to the surface of a detector element, so that a radiation detector optimised for the detection of such radiation can be relatively thin. On the other hand, radiation such as beta particles, x-rays or gamma-rays tends to penetrate the material of a detector element to a greater depth and to be absorbed substantially uniformly throughout the bulk of the detector element.

It is an object of the invention to provide a single detector which is able to detect such different types of radiation optimally, or which can provide different types of information about a single type of radiation.

SUMMARY OF THE INVENTION

According to the invention there is provided a detector for ionising radiation comprising at least first and second diamond detector elements connected electrically to a common contact, with respective first and second contacts connected to the first and second detector elements, so that the detector simultaneously provides first and second output signals corresponding to radiation incident on the detector elements.

Preferably the first and second detector elements are optimised for the detection of different types of radiation, or for the detection of different parameters of a particular type of radiation.

The first and second detector elements may be formed as respective first and second layers of diamond material in contact with a common metallic or semi-conductor layer.

In a preferred embodiment of the invention, the first layer comprises a relatively thick layer of diamond material and the second layer comprises a relatively thin layer of diamond material.

The common metallic or semi-conductor layer may comprise a material selected from the group consisting of titanium, tungsten, molybdenum and boron doped diamond.

The first layer may have a thickness of between 0.3 mm and 1.5 mm and a collection distance of at least 20 μm, preferably at least 50 μm, and even more preferably a distance of 300 μm or more. The first layer may be optimised for the detection of beta particles, x-rays and gamma rays.

The second layer may have a thickness of between 10 μm and 40 μm and may be optimised for the detection of alpha particles.

The detector may further include respective conductive layers on the outer surfaces of the first and second layers of diamond material, which preferably comprise a material selected from the group consisting of titanium, tungsten, molybdenum and boron doped diamond.

Respective active contacts may be connected to the conductive layers.

The invention also extends to a radiation detector apparatus comprising a detector as defined above, and further comprising bias means arranged to apply respective bias voltages to the first and second diamond detector elements, and first and second amplifiers having inputs connected to the first and second diamond detector elements and arranged to generate respective first and second amplified output signals corresponding to radiation incident on the detector elements

BRIEF DESCRIPTION OF THE DRAWING

The drawing is a highly schematic sectional view of a radiation detector according to the invention, with associated electronic circuitry.

DESCRIPTION OF AN EMBODIMENT

The illustrated radiation detector comprises a first, relatively thick diamond layer 10 and a second, relatively thin diamond layer 12 on either side of a layer 14 of metal or semi-conductive material which serves as a common contact or electrode. The layers 10 and 12 are optimised for the detection of different kinds of ionising radiation, so that a single, unitary radiation detector element is provided which can effectively detect different types of radiation. Alternatively, for example, the detector of the invention could be used for the simultaneous or sequential measurement of partial energy loss of a particle (measured in the thin layer 12) and total particle energy (measured in the thick layer 10).

A prototype radiation detector of the invention was manufactured by commencing with the layer 10, which was a layer of high quality diamond produced by chemical vapour deposition (CVD) with a thickness between 0.3 mm and 1.5 mm and a collection distance of 20 μm, but typically at least 50 μm and, depending on the application, possibly up to 300 μm or more.

Collection distance and its determination are known in the art. Radiation such as UV, x-rays and gamma rays impinging on diamond can form electron/hole pairs which drift under an applied voltage between electrodes. Typically, for penetrating radiation such as beta and gamma rays, the electrodes are placed on opposite surfaces of a diamond layer whose thickness is typically 200 - 700 μm, but can range from less than 100 μm to greater than 1000 μm, and the charge carriers (electrons/holes) drift through the thickness of the layer. For highly absorbed radiation which penetrates only a few μm into the diamond, such as alpha radiation or UV radiation with energies near or above that of the band gap, then inter-digitated electrode arrangements on the same face of the diamond layer may be used; this face may be planar or with the electrodes placed in relationship to surface structures such as grooves.

However, the electrons and holes have finite mobilities and lifetimes so they move only a certain distance before recombining. When an event occurs (e.g. impingement of beta particles) which forms charge carriers, then to first order the total signal from the detector depends on the average distance moved by the charge carriers. This charge displacement is a product of the carrier mobility and the applied electric field (which gives the charge drift velocity) and the recombination lifetime of the carriers before trapping or recombination stops its drift. This is the collection distance which can also be considered as the volume of charge swept to the electrode. The purer the diamond (or the lower the level of uncompensated traps) or the lower the level of crystalline imperfections, the higher the mobility of the carriers and/or their lifetimes.

The next step is the application of the conductive layer 14 to the layer 10. The conductive layer can comprise a metal which adheres to CVD diamond, such as titanium (Ti), tungsten (W), molybdenum (Mo) or other suitable metals. Alternatively, the layer 14 can comprise a substantially conductive semi-conductor layer such as boron doped diamond.

The layer 12 is grown by a CVD process on top of the layer 14 to a thickness optimised for the detection of a different form of radiation compared with that for which the layer 10 is optimised. (In the prototype, the layer 10 was optimised for the detection of beta particles, x-rays and gamma-rays, while the layer 12 was optimised for the detection of alpha particles). In the prototype, the layer 12 had a thickness between 10 μm and 40 μm.

An alternative method of forming the radiation detector is to grow the layers 10 and 12 separately, and then to adhere the conductive layer 14 to one of these layers. The free surface of the conductive layer 14 can then be bonded to the other of the layers 10 or 12.

At one edge of the detector element, a small portion of the layer 12 was removed by a known technique such as oxygen plasma etching, ion beam milling/etching or laser ablation to expose a section 16 of the common contact/electrode 14. (Alternatively, at the time the layer 12 is grown, a section of the layer 14 may be masked. This would prevent the layer 12 from growing

on the masked section, rather than having to remove a portion of it after growth.) The section 16 serves as a common ground contact for the respective layers of the detector elements. In addition, conductive layers 18 and 20 were applied to the outer surfaces of the layers 10 and 12, respectively, to permit the connection of respective active contacts 22 and 24. The conductive layers 18 and 20 can comprise the same metal as that used for the layer 14, ie. Ti, W, Mo or other suitable metals.

The respective contacts are used to bias the respective active layers of the device and to connect the detector elements to suitable electronics.

As shown in the Figure, the contact 22 is connected to an input of a charge sensitive or operational preamplifier A_1 via a coupling capacitor C_1 while the contact 24 is connected to the input of a similar amplifier A_2 via a coupling capacitor C_2. Respective bias voltages V_1 and V_2 are applied to the contacts 22 and 24 via resistors R_1 and R_2. Typically, the bias voltages are 0.1 to 3V/μm. The sign of the applied bias voltage (positive or negative) may vary from what is indicated in the Figure, depending on the application and the material selected for the common contact/electrode.

In a variation of the invention, the metal conductive layer 14 can be replaced by a CVD diamond boron doped layer. This has the advantage that the layer 14, and subsequently the layer 12, can both be grown epitaxially on the layer 10, resulting in the layer 12 being of a higher quality. This is because the quality

(for charge collection efficiency) is known to increase with the thickness of the layer. In the case of the above described example, the layer 12 will typically be polycrystalline in nature and will have a large component of the nucleation grain structure, which is known to be of relatively poor quality, whereas in the second example, the layer 12 will start to grow replicating the grain structure of the layer 14, which in turn should replicate that of the layer 10.

There will be a small amount of interaction between the two layers, for example, the generation of a small signal in the layer 12 due to the absorption of beta particles, but this will be in the ratio of the respective thicknesses of the layers 10 and 12, which can be made to be over a factor of 10.

In other applications, it is required to make two simultaneous measurements of the same particle(s) using a transmission detector which measures the partial energy loss in a thin transmission detector (ΔE), and total particle energy in an absorbing detector (E). From accurate measurement of both E and ΔE it is possible to calculate the mass of the particle and thus differentiate between light charged particles which have a similar mass, eg. protons, deuterons, and ^3He ions. In this type of application, the requirement on the transmission detector is that it should be sufficiently thin to allow transmission of the particles of interest, which in certain applications can limit the thickness in a diamond detector to 40 μm or less, making the detector potentially fragile. The dual detector arrangement provides both the measurement of both ΔE and E in one device, and mechanical support for the otherwise fragile ΔE detector. The latter

makes it more robust and suitable for larger areas, and also give the possibility of reducing further its thickness so that the lower energy cutoff is reduced and the energy straggling is improved. In this type of application it is important to select an interlayer of the correct thickness and properties in order to minimise the error introduced to the measure of E_1 but it does avoid the need for two separate contact layers on separate ΔE and E detectors, so that overall the system design is simplified.

The concept of the invention could easily be extended to a device having more that two detector layers. For example, such a device might be used for the detection of more than two different types of radiation of different penetration or energy loss characteristics.

CLAIMS:

1. A detector for ionising radiation comprising at least first and second diamond detector elements connected electrically to a common contact, with respective first and second contacts connected to the first and second detector elements, so that the detector simultaneously provides first and second output signals corresponding to radiation incident on the detector elements.

2. A detector according to claim 1 wherein the first and second detector elements are optimised for the detection of different types of radiation.

3. A detector according to claim 1 wherein the first and second detector elements are optimised for the detection of different parameters of a particular type of radiation.

4. A detector according to any one of claims 1 to 3 wherein the first and second detector elements are formed as respective first and second layers of diamond material in contact with a common metallic or semi-conductor layer.

5. A detector according to claim 4 wherein the first layer comprises a relatively thick layer of diamond material and the second layer comprises a relatively thin layer of diamond material.

6. A detector according to claim 4 or claim 5 wherein the common metallic or semi-conductor layer comprises a material selected from the group consisting of titanium, tungsten, molybdenum and boron doped diamond.

7. A detector according to any one of claims 4 to 6 wherein the first layer has a thickness of between 0.3 mm and 1.5 mm.

8. A detector according to claim 7 wherein the first layer has a collection distance of at least 20 μm.

9. A detector according to claim 8 wherein the first layer has a collection distance of at least 50 μm.

10. A detector according to claim 9 wherein the first layer has a collection distance of 300 μm or more.

11. A detector according to any one of claims 4 to 10 wherein the first layer is optimised for the detection of beta particles, x-rays and gamma rays.

12. A detector according to any one of claims 4 to 11 wherein the second layer has a thickness of between 10 μm and 40 μm.

13. A detector according to any one of claims 4 to 12 wherein the second layer is optimised for the detection of alpha particles.

14. A detector according to any one of claims 4 to 13 further including respective conductive layers on the outer surfaces of the first and second layers of diamond material.

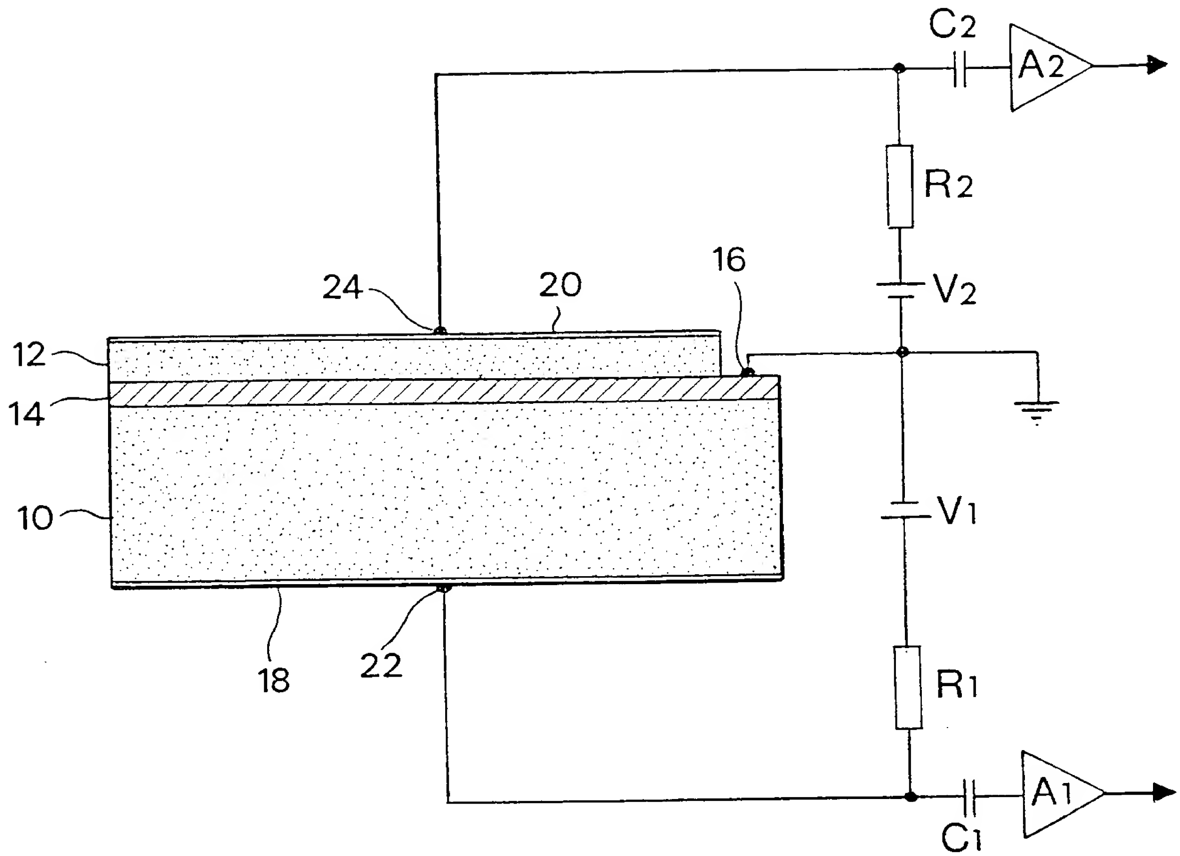
15. A detector according to claim 14 wherein the conductive layers comprise a material selected from the group consisting of titanium, tungsten, molybdenum and boron doped diamond.

16. A detector according to claim 14 or claim 15 including respective active contacts connected to the conductive layers.

17. A detector substantially as herein described with reference to the accompanying drawing.

18. Radiation detector apparatus comprising a detector according to any one of claims 1 to 17, bias means arranged to apply respective bias voltages to the first and second diamond detector elements, and first and second amplifiers having inputs connected to the first and second diamond detector elements and arranged to generate respective first and second amplified output signals corresponding to radiation incident on the detector elements.

19. Radiation detector apparatus substantially as herein described with reference to the accompanying drawing.


C2
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INTERN[hole punch]NAL SEARCH REPORT

Int[hole punch]ional Application No
PCT/IB 99/01002

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G01T1/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G01T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 00456 A (IMPERIAL COLLEGE ;HASSARD JOHN FRANCIS (GB); GODDARD ANTONY JOHN H) 3 January 1997 (1997-01-03) abstract column 3, line 23 - column 4, line 13 column 5, line 31 - column 6, line 18 column 7, line 1 - column 8, line 7 column 13, line 4 - line 12 figures ---	1,2, 17-19
A	US 3 450 879 A (SEPPI EDWARD J) 17 June 1969 (1969-06-17) column 1, line 51 - line 65 column 2, line 49 - line 54 column 3, line 26 - line 42 figures ---	1,4, 17-19

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[X] Further documents are listed in the continuation of box C.

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 381 517 A (DE BEERS IND DIAMOND) 8 August 1990 (1990-08-08) abstract column 1, line 46 - column 3, line 11 figures	1

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB 99/01002

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